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Use of a Krypton Isotope for Rapid Ion Changeover at the Lawrence Berkeley Laboratory 88-Inch Cyclotron

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September 1, 1989



National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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FOR RAPID ION CHANGEOVER AT THE LAWRENCE
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ABSTRACT

An isotope of krypton, Kr^{86} , has been combined with a mix of Ar, Ne, and N ions at the electron cyclotron resonance (ECR) source, at the Lawrence Berkeley Laboratory cyclotron, to provide rapid ion changeover in Single Event Phenomena (SEP) testing. The new technique has been proved out successfully by a recent Jet Propulsion Laboratory (JPL) test in which it was found that there was no measurable contamination from other isotopes.

CONTENTS

1.	INTRODUCTION	1
2.	TECHNICAL DISCUSSION	1
3.	CONCLUSION	2

Figure

1.	Ion Flux Overlap	3
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Table

1.	Cyclotron Parameters for Ion "Cocktail"	2
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1. INTRODUCTION

Tests for single event phenomena (SEP) have been undertaken by JPL and others at various heavy ion accelerators since 1979, when it was demonstrated that the heavy ions provided by accelerators could be used to simulate cosmic ray heavy ions and other radiation environments in space. One of the primary radiation sources is the 88-in. cyclotron at the Lawrence Berkeley Laboratory (LBL), which has been used for several dozen experiments. This source has the capability of providing high energy Kr, Ar, Ne, N, and many other ions useful for SEP characterization of electronics used in spacecraft and satellites.

During the course of testing, LBL upgraded the cyclotron by installing an ECR (electron cyclotron resonance) source. This eliminated frequent, lengthy downtimes due to the short lifetime of the old Penning Ion Gauge sources. Later it was found that several ions of specified energy (Ar, Ne, N) could be introduced at once by the ECR and separated in a matter of minutes by RF tuning the cyclotron. Thus an ion "cocktail" became available which permitted very rapid ion changeover for testing with any one of the selected ions. However, one very important ion, 150 to 400 MeV krypton, used to measure the worst-case ions in space, was not a part of that "cocktail," because a natural krypton isotope was itself an unacceptable contaminant.

2. TECHNICAL DISCUSSION

On July 18, 1988, the Jet Propulsion Laboratory (JPL) first successfully expanded the extent of the high energy ion "cocktail" at LBL by using a single isotope of krypton Kr^{86} as part of the Ar/Ne/N mix. The inclusion of the isotope allowed switching between all four ion beams in only a few minutes, because the isotopic mass of the Kr^{86} isotope was sufficiently different to remove the threat of contamination. The ECR source emits ions into the cyclotron at a pretuned, dimensionless value of A/Q (atomic number/charge state) which is established by the magnetic field setting on the ECR. Tuning can select among different ions having slightly different values of A/Q , but there is a measurable overlapping of ions when the A/Q values of each ion are too close.

In Table 1, the "cocktail" ions, energies at the JPL target chamber (after passing through a scattering foil) and charge state are listed with their A/Q values and the RF delta frequency change (with respect to an argon reference) required to select each ion. Potential contaminants, including Kr^{80} with a 2.27 percent abundance in natural krypton, are also shown. It will be noted that the new Kr^{86} beam has a different A/Q value from the other ions, but there still remains a certain degree of ion overlap in the injection beam from the ECR.

Table 1. Cyclotron Parameters for Ion "Cocktail"

Ion (Charge State)	Energy (MeV)	A/Q	RF Frequency (Delta) (kHz)
<u>New Ion</u>			
Kr ⁸⁶ + 17	316	5.06	-163.250
<u>"Cocktail" Ions</u>			
N ¹⁵ + 3	62.5	5.00	-13.416
Ne ²⁰ + 4	80.7	5.00	-7.962
Ar ⁴⁰ + 8	156	5.00	0.0
<u>Potential Contaminants</u>			
Si ³⁰ + 6	118	5.00	-0.936
Cl ³⁵ + 7	134	5.00	-0.716
Cu ⁶⁵ + 13	241	5.00	2.416
Kr ⁸⁰ + 16	291	5.00	1.486

The degree of ion-overlapping fluxes, shown qualitatively in Figure 1, was measured at the ECR analyzing magnet. The ECR analyzing magnet was set for an A/Q value of 5.025 throughout this test. The cyclotron resonance width is approximately 3 kHz FWHM [full width half maximum], so it is not possible to separate the Kr⁸⁰ + 16 contamination beam from the Ar⁴⁰ + 8 beam. This explains why it is necessary to obtain a nearly isotopically pure Kr⁸⁶ gas to be used for the new "cocktail." The Kr⁸⁰ (an impurity with the isotope) and Cu⁶⁵ (from the ECR walls) were measured with silicon detectors (at a total fluence of 10⁶ ions/cm²) to be less than 3 parts per million (ppm). The other contaminants, present in the ECR from recent earlier test runs, were measured for this test only as: Cl³⁵ @ 1000 ± 200 ppm, and Si³⁰ @ 700 ± 200 ppm. Beam energy measurements and contamination searches were taken before, during, and after the test.

3. CONCLUSION

The new four-ion "cocktail" performed flawlessly, with changeovers back and forth to the krypton ion in minutes. No detectable Kr contamination was found which would affect the results of lower atomic number (Z) and less ionizing ions. This new beam capability saves many hours of expensive tuning time at the cyclotron and also greatly facilitates the testing logistics and scheduling with collaborators.

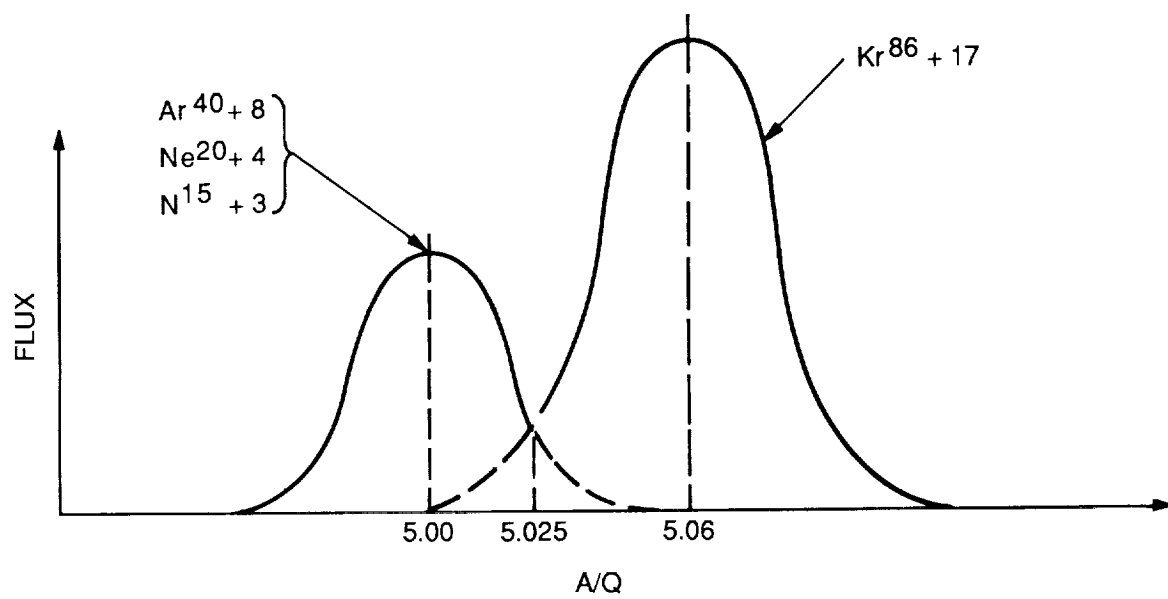


Figure 1. Ion Flux Overlap

